Gases in the atmosphere

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20% O_2

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Types of Motion

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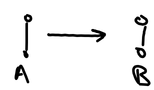
Types of Motion

Translational Motion



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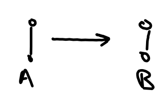
Types of Motion

Translational Motion



Vibrational Motion

Gases in the atmosphere

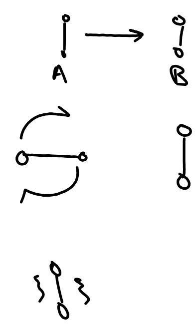
78% N_2
20% O_2
~ 2% Ar, CO_2
trace He, Ne, CH_4

Types of Motion

Translational Motion

Rotational Motion

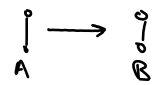
Vibrational Motion



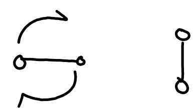
Types of Motion

liquids + gases can do all 3 kinds of Motion

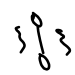
- Translational Motion

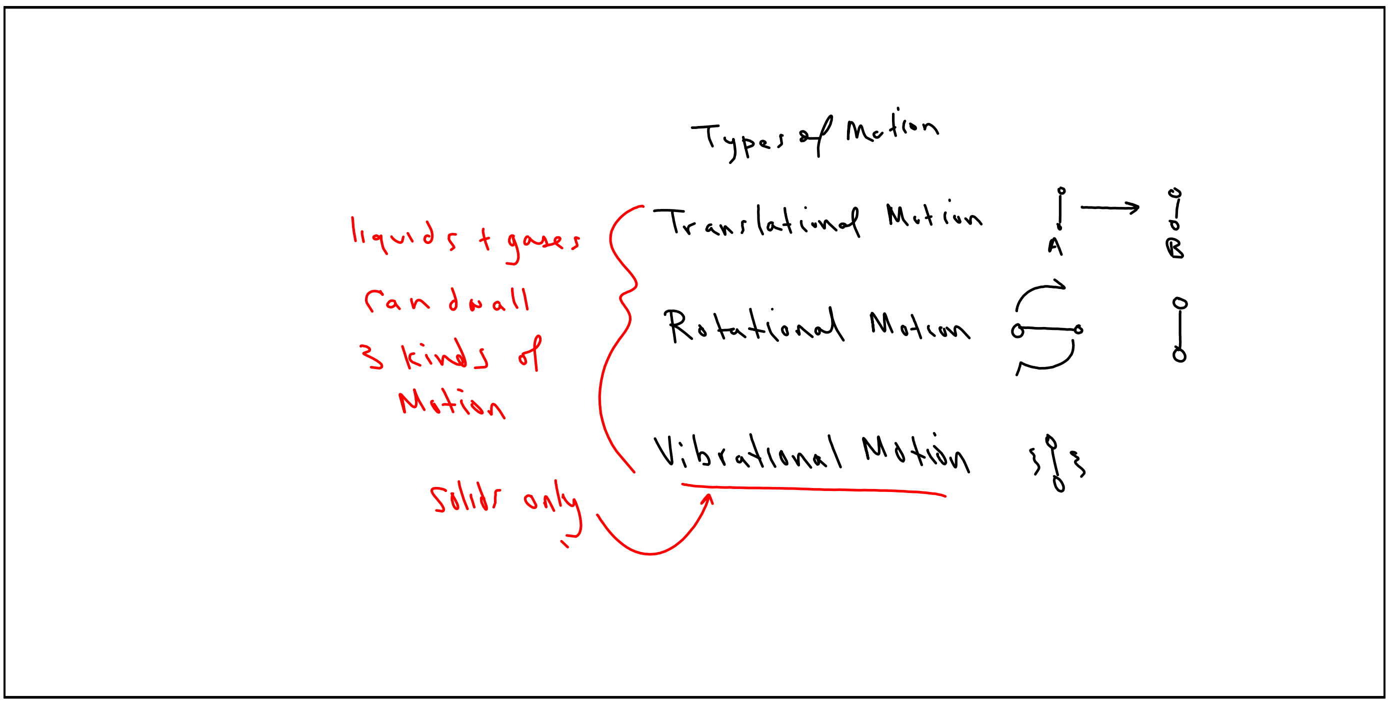


- Rotational Motion



- Vibrational Motion




Types of Motion
liquids + gases
can do all
3 kinds of
Motion
Translational Motion
A
B
Rotational Motion
Vibrational Motion
Solids only

Ideal Gases -

Ideal Gases - any gas that behaves according to the Kinetic Molecular Theory (KMT)

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KMT

1. All samples of a gas consist of large #'s of tiny particles
2. All particles are in a const. state of motion
3. All particles undergo elastic collisions

Ideal Gases - any gas that behaves according to the Kinetic Molecular Theory (KMT)

KMT

1. All samples of a gas consist of large #'s of tiny particles
2. All particles are in a const. state of motion
3. All particles undergo elastic collisions

   No KE lost

Ideal Gases - any gas that behaves according to the Kinetic Molecular Theory (KMT)

KMT

① All samples of a gas consist of large #'s of tiny particles

② All particles are in a const. state of motion

③ All particles undergo elastic collisions

No KE lost

④ No attractive forces b/w molecules

Ideal Gases - any gas that behaves according to the Kinetic Molecular Theory (KMT)

KMT

1. All samples of a gas consist of large #'s of tiny particles
2. All particles are in a const. state of motion
3. All particles undergo elastic collisions — No KE lost
4. No attractive forces b/w molecules
5. KE of particles is directly prop to the Temp.

Ideal Gases - any gas that behaves according to the Kinetic Molecular Theory (KMT)

KMT

① All samples of a gas consist of large #'s of tiny particles

② All particles are in a const. state of motion

③ All particles undergo elastic collisions

No KE lost

④ No attractive forces b/w molecules

⑤ KE of particles is directly prop to the Temp.

As T↑, KE↑ (speed)

5 props of gases

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Expansion / Compressible
(No def volume!)

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Low Densities

5 props of gases

Expansion / Compressible
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<u>Low Densities</u> - large volume
causes Low D

$\frac{g}{L}$

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Diffusion

Diffusion - spreading/mixing in the absence of air currents

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<u>Fluidity</u> - molecules can easily past each other

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Fluidity - molecules can easily past each other (pourable)

Qualitative description of
Ideal gas behavior

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4 variables

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Ideal gas behavior

4 <u>variables</u>

Temperature (T)

Qualitative description of
Ideal gas behavior

4 variables

Temperature (T) - Avg KE

Qualitative description of
Ideal gas behavior

4 variables

Temperature (T) - Avg KE
How fast molecules
are moving

Qualitative description of
Ideal gas behavior

4 variables

Temperature (T) - Avg KE
How fast molecules
are moving

moles (n) -

Qualitative description of
Ideal gas behavior

4 variables

Temperature (T) - Avg KE
How fast molecules
are moving

moles (n) - numbers of
particles

Qualitative description of
Ideal gas behavior

4 variables

Temperature (T) - Avg KE
How fast molecules are moving

Volume (V) -

moles (n) - numbers of particles

Qualitative description of
Ideal gas behavior

4 variables

Temperature (T) - Avg KE
How fast molecules
are moving

moles (n) - numbers of
particles

Volume (V) - space occupied

Qualitative description of
Ideal gas behavior

4 variables

Temperature (T) - Avg KE
How fast molecules
are moving

moles (n) - numbers of
particles

Volume (V) - space occupied

Pressure (P)

Qualitative description of
Ideal gas behavior

4 variables

Temperature (T) - Avg KE
How fast molecules
are moving

moles (n) - numbers of
particles

Volume (V) - space occupied

Pressure (P) - # of collisions
particles make

P vs. V @ const T + n

P vs. V @ const T + n

P vs. V @ const T + n

If V ↑, P ↓ (vice versa)
B/c

P vs. V @ const T + n

If V ↑, P ↓ (vice versa)
B/c in a larger space there
a less collisions b/w molec
so P ↓

P vs. V @ const T + n

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V vs T @ const P + n

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V vs T @ const P + n

If T ↑, V ↑, B/c if particles move faster, they spread out farther apart so V ↑

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If V ↑ , P ↓ (vice versa)
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V vs T @ const P + n

If T ↑ , V ↑ , B/c if particles move faster, they spread out farther apart so V ↑

P vs T @ const V + n

If T ↑ , P ↑ b/c particles move faster, collisions increase so P ↑

V vs n @ const T + P

V vs n @ const T + P

If n ↑, V ↑ b/c more gas particles occupy a larger space.

V vs n @ const T + P

If n ↑, V ↑ b/c more gas particles occupy a larger space.

P vs n @ const T + V

V vs n @ const T + P

If n ↑, V ↑ b/c more gas particles occupy a larger space.

P vs n @ const T + V

If n ↑, P ↑ b/c more particles will collide more frequently.

Blakeney

Measuring P

Measuring P

1643 Evangalista Torricelli

Measuring P

1643 Evangalista Torricelli

Measured atmospheric P

using a Hg Barometer

Measuring P

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Measured atmospheric P

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Standard Pressure = 760 mmHg = 760 torr

Measuring P

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Measured atmospheric P
using a Hg Barometer

Standard Pressure = 760 mmHg = 760 torr = 1.0 atm
(atmospheres)

Measuring P

1643 Evangalista Torricelli

Measured atmospheric P

using a Hg Barometer

Standard Pressure = 760 mmHg = 760 torr = 1.0 atm = 101.3 kPa

(atmospheres) (kilo Pascals)

Converting P's

Converting P's

252 torr = ? atm

73_ mmHg = ? kPa

6.42 atm = ? mmHg

Converting P's

252 torr = ? atm

252 torr

73? mmHg = ? kPa

6.42 atm = ? mmHg

Converting P's

252 torr = ? atm

$252\ torr \times \frac{atm}{torr}$

73? mmHg = ? kPa

6.42 atm = ? mmHg

Converting P's

252 torr = ? atm

$252 \text{ torr} \times \frac{1 \text{ atm}}{760 \text{ torr}}$

734 mmHg = ? kPa

6.42 atm = ? mmHg

Converting P's

252 torr = ? atm

$$252 \text{ torr} \times \frac{1 \text{ atm}}{760 \text{ torr}} = 0.33 \text{ atm}$$

735 mmHg = ? kPa

6.42 atm = ? mmHg

Converting P's

252 torr = ? atm

$252 \text{ torr} \times \frac{1 \text{ atm}}{760 \text{ torr}} = 0.33 \text{ atm}$

730 mmHg = ? kPa

$730 \text{ mmHg} \times \frac{101.3 \text{ kPa}}{760 \text{ mmHg}} = 97.3 \text{ kPa}$

6.42 atm = ? mmHg

Converting P's

252 torr = ? atm

$$252 \text{ torr} \times \frac{1 \text{ atm}}{760 \text{ torr}} = 0.33 \text{ atm}$$

730 mmHg = ? kPa

$$730 \text{ mmHg} \times \frac{101.3 \text{ kPa}}{760 \text{ mmHg}} = 97.3 \text{ kPa}$$

6.42 atm = ? mmHg

$$6.42 \text{ atm} \times \underline{\hspace{2cm}}$$

Converting P's

252 torr = ? atm

$$252 \text{ torr} \times \frac{1 \text{ atm}}{760 \text{ torr}} = 0.33 \text{ atm}$$

730 mmHg = ? kPa

$$730 \text{ mmHg} \times \frac{101.3 \text{ kPa}}{760 \text{ mmHg}} = 97.3 \text{ kPa}$$

6.42 atm = ? mmHg

$$6.42 \text{ atm} \times \frac{760 \text{ mmHg}}{1.0 \text{ atm}} = 4880 \text{ mmHg}$$

Gas Laws

Gas Laws

1662 Robert Boyle

Gas Laws

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↳ worked w/ V & P

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If gas V doubled, P decreased by $\frac{1}{2}$

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P + V are inversely prop!

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$xy = k$

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$x y = k$ (const)

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$V\,P = k$

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$xy = k$ (const)

$V_1 P_1 = K$

$V_2 P_2 = K$

Gas Laws

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$\rightarrow V_1 P_1 = V_2 P_2$

Gas Laws

1662 Robert Boyle

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If gas V doubled, P decreased by $\frac{1}{2}$

P + V are inversely prop!

$x y = K$ (const)

$V_1 P_1 = K$

$V_2 P_2 = K$

$V_1 P_1 = V_2 P_2$

Boyle's Law

@ const nT.

If a 35.0 mL sample of
He initially has a pressure
of 1120 torr, what will the new
P be if the V increases to
37.2 mL?

If a 35.0mL sample of
He initially has a pressure
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P be if the V increases to
37.2mL?

V_1 V_2

P_1 P_2

If a 35.0mL sample of He initially has a pressure of 1120 torr, what will the new P be if the V increases to 37.2mL?

$V_1 = 35.0mL$ V_2

$P_1 = 1120 torr$ P_2

If a 35.0mL sample of
He initially has a pressure
of 1120 torr, what will the new
P be if the V increases to
37.2mL?

$V_1 = 35.0mL$ $V_2 = 37.2mL$

$P_1 = 1120torr$ P_2

If a 35.0mL sample of He initially has a pressure of 1120 torr, what will the new P be if the V increases to 37.2mL?

$V_1 = 35.0mL$ $V_2 = 37.2mL$

$P_1 = 1120torr$ $P_2 = ?$

If a 35.0mL sample of He initially has a pressure of 1120 torr, what will the new P be if the V increases to 37.2mL?

$V_1 = 35.0mL$ $V_2 = 37.2mL$

$P_1 = 1120 torr$ $P_2 = ?$

$$P_2 = \frac{V_1 P_1}{V_2}$$

If a 35.0 mL sample of He initially has a pressure of 1120 torr, what will the new P be if the V increases to 37.2 mL?

$V_1 = 35.0\,mL$ $V_2 = 37.2\,mL$

$P_1 = 1120\,torr$ $P_2 = ?$

$$P_2 = \frac{V_1 P_1}{V_2}$$

$$= \frac{(35.0\,mL)(1120\,torr)}{37.2\,mL}$$

$=$

If a 35.0 mL sample of He initially has a pressure of 1120 torr, what will the new P be if the V increases to 37.2 mL?

$V_1 = 35.0\,mL$ $V_2 = 37.2\,mL$

$P_1 = 1120\,torr$ $P_2 = ?$

$$P_2 = \frac{V_1 P_1}{V_2}$$

$$= \frac{(35.0\,mL)(1120\,torr)}{37.2\,mL}$$

$$= 1054\,torr$$

A sample of a gas has a pressure of 550 torr. If the gas V changes to 468 mL and the p is 0.780 atm, what was the original V?

A sample of a gas nat
a pressure of 550 torr
If the gas V changes
to 468 mL and the p is
0.780 atm what was the
original V?

V_1 V_2

P_1 P_2

A sample of a gas has a pressure of 550 torr
If the gas V changes to 468 mL and the p is 0.780 atm what was the original V?

$V_1 = ?$ $V_2 = 468 mL$

$P_1 = 550 torr$ $P_2 = 0.780 atm$

A sample of a gas has
a pressure of 550 torr
If the gas V changes
to 468 mL and the p is
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original V?

$V_1 = ?$ $V_2 = 468\,mL$

$P_1 = 550\,torr$ $P_2 = 0.780\,atm$

A sample of a gas has at a pressure of 550 torr. If the gas V changes to 468 mL and the p is 0.780 atm what was the original V?

$V_1 = ?$ $V_2 = 468\,mL$

$P_1 = 550\,torr$ $P_2 = 0.780\,atm \times \frac{760\,torr}{1\,atm} = 593\,torr$

A sample of a gas has at a pressure of 550 torr. If the gas V changes to 468 mL and the P is 0.780 atm what was the original V?

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$V_1 = \frac{V_2 P_2}{P_1}$

=

A sample of a gas has a pressure of 550 torr. If the gas V changes to 468 mL and the p is 0.780 atm, what was the original V?

$V_1 = ?$ $V_2 = 468\text{ mL}$

$P_1 = 550\text{ torr}$ $P_2 = 0.780\text{ atm} \times \frac{760\text{ torr}}{1\text{ atm}} = 593\text{ torr}$

$$V_1 = \frac{V_2 P_2}{P_1}$$

$$= \frac{(468\text{ mL})(593\text{ torr})}{(550\text{ torr})}$$

A sample of a gas has at a pressure of 550 torr. If the gas V changes to 468 mL and the P is 0.780 atm what was the original V?

$V_1 = ?$ $V_2 = 468 mL$

$P_1 = 550 torr$ $P_2 = 0.780 atm \times \frac{760 torr}{1 atm} = 593 torr$

$$V_1 = \frac{V_2 P_2}{P_1}$$

$$= \frac{(468 mL)(593 torr)}{(550 torr)}$$

$$= 504 mL$$

1787 Jacques Charles

1787 Jacques Charles

worked Vol + Temp of gases

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worked Vol + Temp of gases

If T increased by 1°, V increased by $\frac{1}{273}$

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If T increased by 1°, V increased by $\frac{1}{273}$

<u>Direct Prop</u>

$$K = \frac{x}{y}$$

1787 Jacques Charles

worked Vol + Temp of gases

If T increased by 1°, V increased by $\frac{1}{273}$

<u>Direct Prop</u>

$K = \frac{x}{y}$ $\frac{V}{T} = k$ @ const P + n

1787 Jacques Charles

worked Vol + Temp of gases

If T increased by 1°, V increased by $\frac{1}{273}$

Direct Prop

$K = \frac{x}{y}$ $\frac{V}{T} = k$ @ const P + n

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If T increased by 1°, V increased by $\frac{1}{273}$

Direct Prop

$K = \frac{x}{y}$ $\frac{V_1}{T_1} = k$ @ const P + n

1787 Jacques Charles

worked Vol + Temp of gases

If T increased by 1°, V increased by $\frac{1}{273}$

Direct Prop

$K = \frac{x}{y}$ $\frac{V_1}{T_1} = k$ @ const P + n

V_2

1787 Jacques Charles

worked Vol + Temp of gases

If T increased by 1°, V increased by $\frac{1}{273}$

Direct Prop

$K = \frac{x}{y}$

$\frac{V_1}{T_1} = k$ @ const P + n

$\frac{V_2}{T_2} = k$

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

or

$V_1 T_2 = V_2 T_1$

1787 Jacques Charles

worked Vol + Temp of gases

If T increased by 1°, V increased by $\frac{1}{273}$

Direct Prop

$K = \frac{x}{y}$ $\frac{V_1}{T_1} = k$ @ const P + n

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$V_1 T_2 = V_2 T_1$ Charles's Law

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If T increased by 1°, V increased by $\frac{1}{273}$

Direct Prop

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$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

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$V_1T_2 = V_2T_1$ Charles's Law

Temp must be in Kelvin

K = °C + 273

1787 Jacques Charles

worked Vol + Temp of gases

If T increased by 1°, V increased by $\frac{1}{273}$

Direct Prop

$K = \frac{x}{y}$ $\frac{V_1}{T_1} = k$ @ const P + n

$\frac{V_2}{T_2} = k$

→ $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

or

$V_1T_2 = V_2T_1$ Charles's Law

Temp must be in Kelvin

$K = °C + 273$

STP - Standard Temp + Pressure

0 °C | 760 torr
273 K | 760 mm Hg
 | 101.3 kPa
 | 1 atm

$V_1T_2 = V_2T_1$ Charles's Law

Temp must be in Kelvin

K = °C + 273

A sample of CH_4 occupies a Volume of 500.2 mL @ 72.0 °C. What will the V of the gas be if the T doubles?

STP - Standard Temp + Pressure

0 °C
273 K

760 mm Hg
101.3 kPa
1 atm

$V_1T_2 = V_2T_1$ Charles's Law

Temp must be in Kelvin
K = °C + 273

A sample of CH_4 occupies a volume of 500.2 mL @ 72.0 °C. What will the V of the gas be if the T doubles?

V_1 V_2

T_1 T_2

$V_1 T_2 = V_2 T_1$ Charles's Law

Temp must be in Kelvin

K = °C + 273

A sample of CH_4 occupies a Volume of 500.2 mL @ 72.0 °C. What will the V of the gas be if the T doubles?

V_1 500.2 mL V_2 = ?

T_1 = 72.0 °C T_2

$V_1T_2 = V_2T_1$ Charles's Law

Temp must be in Kelvin

K = °C + 273

A sample of CH_4 occupies a Volume of 500.2 mL @ 72.0 °C. What will the V of the gas be if the T doubles?

V_1 500.2 mL V_2 = ?

T_1 = 72.0 °C + 273 = 345 K T_2 = 144 °C + 273 = 415 K

$V_1 T_2 = V_2 T_1$ Charles's Law

Temp must be in Kelvin

K = °C + 273

A sample of CH_4 occupies a Volume of 500.2mL @ 72.0°C. What will the V of the gas be if the T doubles?

V_1 500.2 mL V_2 = ?

T_1 = 72.0°C + 273 (×2) T_2 = 144°C + 273

345K   417K

$V_1T_2 = V_2T_1$ Charles's Law

Temp must be in Kelvin

K = °C + 273

A sample of CH_4 occupies a Volume of 500.2mL @ 72.0°C. What will the V of the gas be if the T doubles?

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T_1 = 72.0°C + 273 ×2 T_2 = 144°C + 273

345K 417K

$$V_2 = \frac{V_1 T_2}{T_1}$$

$V_1 T_2 = V_2 T_1$ Charles's Law

Temp must be in Kelvin

K = °C + 273

A sample of CH_4 occupies a Volume of 500.2 mL @ 72.0 °C. What will the V of the gas be if the T doubles?

V_1 500.2 mL V_2 = ?

T_1 = 72.0 °C + 273 = 345 K (×2) T_2 = 144 °C + 273 = 417 K

$$V_2 = \frac{V_1 T_2}{T_1} = \frac{(500.2\text{ mL})(417\text{ K})}{345\text{ K}}$$

$V_1T_2 = V_2T_1$ Charles's Law

Temp must be in Kelvin

K = °C + 273

A sample of CH_4 occupies a volume of 500.2 mL @ 72.0 °C. What will the V of the gas be if the T doubles?

V_1 500.2 mL V_2 = ?

T_1 = 72.0 °C + 273 = 345 K (×2) T_2 = 144 °C + 273 = 417 K

$$V_2 = \frac{V_1 T_2}{T_1} = \frac{(500.2\text{ mL})(417\text{ K})}{345\text{ K}}$$

= **604.6 mL**

$V_1 T_2 = V_2 T_1$ Charles's Law

Temp must be in Kelvin

K = °C + 273

Combined Gas Law

Combined Gas Law

Boyle's Law - $V_1P_1 = V_2P_2$

Combined Gas Law

Boyle's Law - $V_1P_1 = V_2P_2$

Charles's Law $V_1T_2 = V_2T_1$

Combined Gas Law

Boyle's Law - $V_1 P_1 = V_2 P_2$

Charles's Law $V_1 T_2 = V_2 T_1$

Gay-Lussac's $P_1 T_2 = P_2 T_1$

Combined Gas Law

		Constant	
Boyle's Law -	$V_1P_1 = V_2P_2$	n	T
Charles's Law	$V_1T_2 = V_2T_1$	n	P
Gay-Lussac's	$P_1T_2 = P_2T_1$	n	V

Combined Gas Law

		Constant
Boyle's Law -	$V_1P_1 = V_2P_2$	n T
Charles's Law	$V_1T_2 = V_2T_1$	n P
Gay-Lussac's	$P_1T_2 = P_2T_1$	n V

Combined Gas Law

		Constant	
Boyle's Law -	$V_1 P_1 = V_2 P_2$	n	T
Charles's Law	$V_1 T_2 = V_2 T_1$	n	P
Gay-Lussac's	$P_1 T_2 = P_2 T_1$	n	V

$V_1 P_1 T_2 = V_2 P_2 T_1$

Combined Gas Law

Combined Gas Law

		Constant	
Boyle's Law -	$V_1P_1 = V_2P_2$	n	T
Charles's Law	$V_1T_2 = V_2T_1$	n	P
Gay-Lussac's	$P_1T_2 = P_2T_1$	n	V

$V_1P_1T_2 = V_2P_2T_1$

Combined Gas Law

T must be in K

If a gas has a V of 18.9mL @
a Temp of 23.0°C & P of
872 torr, what will the V
of the gas be @ STP?

If a gas has a V of 18.9mL @ a Temp of 23.0°C & P of 872 torr, what will the V of the gas be @ STP?

V_1 V_2

P_1 P_2

T_1 T_2

If a gas has a V of 18.9mL @ a Temp of 23.0°C & P of 892 torr, what will the V of the gas be @ STP?

$V_1 = 18.9mL$ V_2

$P_1 = 892\ torr$ P_2

$T_1 = 23.0°C + 273 = 296K$ T_2

If a gas has a V of 18.9mL @ a Temp of 23.0°C & P of 892 torr, what will the V of the gas be @ STP?

$V_1 = 18.9mL$ $V_2 = ?$

$P_1 = 892$ torr $P_2 = 760$ torr

$T_1 = 23.0°+273$ $= 296K$ $T_2 = 273K$

If a gas has a V of 18.9mL @ a Temp of 23.0°C & P of 892 torr, what will the V of the gas be @ STP?

$V_1 = 18.9\text{mL}$ $V_2 = ?$

$P_1 = 892\text{ torr}$ $P_2 = 760\text{ torr}$

$T_1 = 23.0 + 273 = 296\text{K}$ $T_2 = 273\text{K}$

$$V_1 P_1 T_2 = V_2 P_2 T_1$$

$$V_2 = \frac{V_1 P_1 T_2}{P_2 T_1}$$

If a gas has a V of 18.9mL @ a Temp of 23.0°C & P of 892 torr, what will the V of the gas be @ STP?

$V_1 = 18.9 mL$ $V_2 = ?$

$P_1 = 892\ torr$ $P_2 = 760\ torr$

$T_1 = 23.0 + 273 = 296K$ $T_2 = 273K$

$V_1 P_1 T_2 = V_2 P_2 T_1$

$$V_2 = \frac{V_1 P_1 T_2}{P_2 T_1} \quad \frac{(18.9mL)(892 torr)(273K)}{(296K)(760 torr)}$$

=

If a gas has a V of 18.9mL @ a Temp of 23.0°C & P of 892 torr, what will the V of the gas be @ STP?

$V_1 = 18.9 mL$ $\quad V_2 = ?$

$P_1 = 892 torr$ $\quad P_2 = 760 torr$

$T_1 = 23.0°C + 273 = 296 K$ $\quad T_2 = 273 K$

$$V_1 P_1 T_2 = V_2 P_2 T_1$$

$$V_2 = \frac{V_1 P_1 T_2}{P_2 T_1} \quad \frac{(18.9 mL)(892 torr)(273 K)}{(296 K)(760 torr)}$$

$$= 20.5 mL$$